Secondary Markets, License Terms and Priority Access Licenses

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1. Introduction

My name is Daniel R. Vincent. I am Professor of Economics at the University of Maryland, College Park where I teach graduate courses in microeconomic theory and industrial organization. I am an economic theorist with a specialization in auction theory and market design. I have published scholarly articles in this area in top economic journals and in policy forums. I served as advisor to the FCC in their evaluation of the performance of the initial major SMR auctions for PCS licenses. I was a member of an outside consulting team (Market Design Incorporated) that provided early models of combinatorial auctions for spectrum. Additionally, I have advised the FCC and Industry Canada, as well as other government agencies on the design of spectrum auctions. I have also provided advice to bidders participating in such auctions. I have served as consultant for the US Department of Justice Antitrust Division and for a variety of third parties on antitrust matters. My CV accompanies this submission.

Verizon Communications has asked me to provide some comments in response to the Notice of Proposed Rulemaking 17-135 (NPRM) on proposed changes to the terms and auction of the Priority Access Licenses (PALs) in the 3.5 GHz band. My comments focus primarily on the length of licenses and their renewability. I will also discuss somewhat more briefly the question of geographic license size.

A central theme in my discussion is the important role of efficient secondary markets in ensuring the efficient allocation of scarce resources over time – in this case, the allocation of the (restricted) rights to the use of the radio-frequency spectrum through the PALs licenses. A well-functioning and liquid secondary market enables a more efficient use of spectrum as conditions vary over time and serves to maximize the value of this resource. Inefficiently short license terms can interfere with the operations of such markets and supplant their role in maximizing the incentives for licensees to make investments that will enhance their value.

2. Secondary Markets

Spectrum licenses are highly durable goods. There is little chance that the physical properties of a radio-frequency band will depreciate with use, though, its value to a particular user can certainly vary over time.

For a collection of as yet unassigned spectrum licenses, auctions are valuable tools to help achieve an efficient initial allocation. The stronger the property rights that are attached to these licenses, the more confident bidders will be in participating in the auctions and the more likely it will be that bidders who expect to most efficiently exploit these property rights will obtain them in the auction. One aspect of strong property rights includes the length of time over which the winning bidder will retain the license. The longer the term of license (and the higher the likelihood of renewal) the more certain a bidder will be about the value of the license it is bidding for.

Furthermore, granting a license for long periods does not necessarily conflict with the desire to ensure that license ownership vary over time in response to changes in comparative values across potential users. In the presence of efficient and liquid secondary markets, incumbent owners who are no longer the most efficient users are able to resell the licenses to emerging alternative users who have better

uses for the asset. And, the assurance that a license owner can resell its license to higher value users in the future increases the willingness to pay of bidders at the initial auction. This assurance may also aid liquidity constrained bidders to obtain financial backing to support such bidding, as a license that can be easily resold represents far less of a capital risk to financial backers.

There appear to be no obvious technical hurdles that might prevent easy resale of spectrum licenses. The rights to use can be easily transferred and the geographic contours can be fairly costlessly modified to suit particular buyers. Furthermore, economic barriers such as, for example, informational asymmetries, appear to be relatively small. Potential buyers and sellers may have private information about their own willingness to pay for a license but it seems unlikely they would enjoy significant asymmetric information about commonly valued properties of the license.[1]

Evidence appears to support the existence of a vibrant secondary market in spectrum. Mayo and Wallsten found that between 2003 and 2008, around 10 Billion MHz-Pops of spectrum licenses changed hands annually each year outside of the FCC auctions.[2] This figure represented approximately the same amount as was sold in the 2006 AWS auction. They found also that between 1998 and 2008, the average time to process license transfers (an approximate measure of barriers to trade in these markets) fell from 151 days to between 30 and 40 days.[3] Economists Inc. reported that this delay had fallen to 10 days by 2009.[4]

An active and fluid secondary market in leased spectrum, as would be encouraged by the proposal in the current NPRM, would also serve to enhance the efficient allocation of spectrum over time. Such policies encourage flexible use of spectrum as operators with highly localized needs (for example warehouses, or hospitals) could carve out specific area uses. This expanded opportunity would be valuable along a number of dimensions. The leases would allow for an optimal mix between the use of a larger license to accommodate a carrier's need for a full footprint and a very narrow focused use within that footprint.

In some ways, short license terms duplicate the functions of an active secondary market by forcing resale of licenses within the short period of the term (and allowing incumbent users to repurchase the licenses if they wish). However, they represent an inflexible, mechanical alternative that can inhibit efficient choices. Secondary markets that generate trades in response to the random emergence of new potential gains from trade allow both parties involved in the trade to optimize the timing and terms of trade. An organized and forced secondary market that arises each time a license term expires imposes a rigid timing structure on parties who would otherwise mutually decide when and if to trade. In the next section, I discuss in more detail how such a crude mechanism can inhibit long-term investment incentives in license use and therefore reduce the total potential value of the licenses.

While secondary markets could conceivably exist in conjunction with short-term licenses, it seems likely that these forced resale markets would tend to draw participants away from the spontaneous secondary

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[1] It is well-known that asymmetries of the latter sort can inhibit the formation of markets entirely as in, for example, Akerlof's classic "Market for Lemons".

[2] These transactions include *pro forma* transactions and, as such, overstate the incidence in which licenses change hands due to changes in use value.

[3] John Mayo and Scott Wallsten, "Enabling Efficient Wireless Communications: The Role of Secondary Spectrum Markets", 2010.

[4] https://ei.com/economists-ink/fall-2009/secondary-spectrum-markets-by-scott-j-wallsten/.

markets, reducing the liquidity of these markets and their effectiveness. This could happen for a variety of reasons. First, it will simply take away some participants who would otherwise be in the secondary markets. Second, because there are fixed costs in acquiring and making a license operable, potential buyers might wish to wait until the resale period in order to maximize their usage term. Finally, if the resale auction offers rebates to incumbents who lose licenses at the forced resale auctions, potential sellers might prefer to wait until the auction to capture the rebates rather than to (efficiently) sell right away in the secondary market.

One concern about longer term licenses centers around the possibility that large incumbent license holders might wish to buy licenses and warehouse them in order to foreclose potential competitors from using them and thereby diminishing the incumbent's pricing power. While this type of "raising rival's costs" incentive is a coherent theoretical possibility, the conditions where such incentives are feasible and profitable require particular contexts and carefully aligned values. The feasibility of such foreclosing strategies can be limited by imposing roll-out provisions as conditions of use as has been successfully used by the FCC in the past. Furthermore, the profitability of foreclosure strategies is limited when the opportunity cost of unused spectrum is very high. The fact that there continues to be a high and growing demand for bandwidth by wireless customers tends to argue against the attractiveness of letting spectrum lie dormant even for (and perhaps especially for) large carriers.

3. Impacts of Short-term Licenses on Investment Incentives

In the appendix, I provide two simple examples that illustrate separate mechanisms by which short term licenses discourage long-term investments in comparison to long-term licenses and the utilization of secondary markets. In this section, I provide a more intuitive description of the examples. Briefly, one issue is that the rigid resale timing implied by short-term licenses prevents incumbent license holders from optimally deciding when to attempt to resell their license. The second issue is that a resale auction effectively fixes the terms of trade on resale in such a way that it can prevent an incumbent user from capturing as much of the incremental surplus created by earlier investments in the license as it could in a secondary market where it negotiates the resale price.

It should be recognized that the presence of secondary markets (as in any context where license ownership can change over time) also *will* reduce incentives to invest in long-term capital improvements. However, this is not necessarily a bad thing on its own. The optimal allocation of licenses will always involve some balancing between some long-term incentives against short-term allocative efficiency. The two stylized examples in the appendix are intended to illustrate how short-term licenses can further discourage investment relative to an active secondary market.

3a) Timing Distortions

Consider an incumbent licensee that has the opportunity to sink an investment in a risky capital improvement, the success or failure of which will only be realized, say, four years later. At some time before or just after that realization, a long-term license holder can always test the secondary market to see if an alternative user exists with a higher realized use value. Whether such a user exists is unknown until the licensee spends some resources to test the market. Abstracting away from holding costs, the license holder might rationally decide to delay testing the secondary market until the uncertainty is realized. If the project succeeds, the payoff may be high enough that there is no need to go to the secondary market. If the project fails, then the secondary market offers a preferable alternative use for

the license and is only needed in this event. In this scenario, an incumbent licensee might be willing to invest even in projects that require relatively high sunk costs.

Suppose, instead, a short-term license is held and the licensee is forced to return the license and rebid after *3* years, that is, before the success of the project is known. If no high value alternative user emerges at the second auction, then the licensee will continue to reap the value of its investment (though it may have to outbid the second best user to do so.). If, however, a high value user arrives at the re-auction, such a user may well be capable of outbidding the incumbent who remains unsure if the project is a success or failure. The incumbent receives no return on its investment in such a circumstance as it loses the license at the re-auction. Its investments are thus stranded. If the likelihood of a high value alternative user arriving at the auction is high enough, the anticipation of this development could be harmful enough to prevent the initial investment even at costs slightly lower than the costs that would have encouraged the investment with long-term licenses.

In this example, the forced timing on resale that is implied by short-term licenses forces incumbent owners either to risk stranding long-term investments or to forego making those investments entirely.

3b) Pricing Distortions

Consider a different investment scenario where the incremental return on initial investment is certain but it is uncertain what the intrinsic value of the license to the incumbent is in the future compared to a potential rival.

Suppose, for example, that both the incumbent licensee and a potential alternative user have equal and independent probabilities of experiencing an increase in intrinsic use-value in the next period. Say this increased value is *100*. Additionally, in the current period, the licensee has the opportunity to sink an investment cost. Doing so raises the value of the license to the licensee alone by *V,* where $0 < V < 100$. In this scenario, with or without the investment, efficient allocation of the license would require changing ownership only if the incumbent did not have an intrinsic increase in use-value and the alternate user did. (Under the assumptions, this event occurs 25% of the time.)

In the event where realizations are such that a change of license is warranted, with long-term licenses and efficient secondary markets, the incumbent would seek to find terms of trade between the two potential users that would satisfy it and lead to an efficient allocation. If the parties had equal bargaining power, they would split the available surplus and negotiate a price for the sale of the license between the use-value of the incumbent (V) and that of the new user (100). The gross return on investment for the incumbent, in this event, is ½ V + ½ 100. Of course, if it had not invested in the capital improvement, whenever this event arises it could still sell the license at a price of ½ 100. Thus, the *incremental* value to the incumbent of the investment when it owns the license, is ½ V.

With short-term licenses, when this event arises, the incumbent has a higher value for its license with the investment than not, but not high enough to outbid the rival. In this case, it fails to reacquire the license at the re-auction and its return on investment is 0. This is also what it would gain in this event if it chose not to invest, so this event strands the sunk cost and fails to compensate the incumbent for any of the lost asset.

4. The Optimal Size of PALs

Ideally, the geographic partition of spectrum licenses should mirror the preferred partitions of the ultimate users of spectrum at auction so that there is no need for these users to try to aggregate up to the desired size at auction or disaggregate down in secondary markets. Of course, in practice, it is rarely obvious what this optimal partition size is and, to complicate the problem further, generally there is disagreement among potential users about the most desired partition.

I have no expertise over engineering aspects of the telecom industry that might determine the optimal partition for spectrum broadly or for the PALs licenses more narrowly so I do not presume to opine on the ideal partition size. In general, I have heard plausible economic arguments both for strongly complementary preferences by bidders (which would argue for larger license size) as well as for substitute preferences (which may argue for smaller size licenses). I imagine both preferences are likely present at most spectrum auctions.

As long as licenses can be both partitioned and aggregated post-auction in secondary markets, one might expect that many deviations from optimal license size at auction can be corrected after the auction. If too large a license size is selected, winners can sell off some licenses and if too small a license size is used and winners fail to acquire the licenses at auction, they can purchase them in the secondary market.

However, there is a sense in which secondary markets are less able to achieve the correct license size when the error lies in the selection of licenses that are too small. This is because of the incentive for sellers to hold out to be the last traders in the secondary market to capture the larger incremental gains. Suppose there are two licenses, A and B, and that ideally the best use of the licenses is by a bidder with complementary preferences. Specifically, suppose the complementary preference bidder values holding both licenses at 100 and has no value for the two licenses individually. Suppose further there are two smaller bidders whose use value is normalized to 0. (So the 100 represents an incremental value over their use value.) It is nevertheless possible, because of the exposure problem, for example, that the small bidders are able to acquire the licenses at auction. In an active secondary market, the large bidder might attempt to negotiate with each of the bidders to acquire the two licenses. Suppose the negotiations involve bargaining where, for example, each party obtains one-half of the gains from trade relative to their outside option. If, as likely would occur, the parties bargain sequentially, then after a deal is made with one license holder, a bargain between the remaining holder and the large acquirer would take place. However, in this circumstance, whatever deal was struck with the first licensee is a sunk cost for the large user. The deal between the large user and the remaining licensee would occur at a price of 50. Anticipating this, the best price that bargainers could agree to in the first trade would be a price of 25. But anticipating this, both A and B owners will recognize the advantage of being the last trader in the sequence. The two incumbent licensees have an incentive try to delay trade until the other comes to a deal, frustrating the need for a speedy re-allocation of licenses.

A further concern about selecting a plan with very small licenses is the resulting sheer number of licenses at auction. I agree with Professor Paul Milgrom that auctions of license areas that number even as high as 70,000 should be *computationally feasible* for common auction mechanisms. The problem with selling a large number of licenses at one auction is not mainly for the auctioneer. These auctions with such a large number of license areas do pose significant burdens on bidders. This is especially so for bidders whose ideal license footprints are larger than that covered by an individual license. In my

experience, even handling a profile of 700 or so licenses requires a great deal of effort and care. Bid sheets must be verified and sometimes authorized by other members of the bidder's firm. If the targeted footprints begin to vary as the auction progresses and prices rise, new business plans may need to be considered and evaluated. With so many licenses sold at a time, more bidder resources are going to be devoted simply to getting bids in on time and correctly verifying them rather than to fully optimizing bid targets and strategies.

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Appendix

A1: Timing Distortions with Short-term Licenses

In this section, I demonstrate by use of a simple, stylized example that, by forcing an incumbent licensee to reacquire its license before it has an opportunity to learn whether a long-term risky investment has been successful, the use of short-term licenses can dampen its incentives to take on such an investment. In contrast, a longer-term license allows it the freedom to select the optimal time to explore whether a better alternative use exists in a secondary market.

Consider a license holder with current license value normalized to zero. The licensee can invest K dollars (as a sunk cost) in a risky venture for infrastructure improvement. Examples might include research into the potential for introducing a new technology, manpower devoted to market a new offering, resources devoted to negotiating siting agreements or physical assets that would be stranded if the licensee fails to realize a successful innovation or sells the license.

The investment realizes a return after T periods. With probability α, the return increases the value of the license by $200,$ otherwise the return is $0.$

At any time, at a cost $c > 0,$ the licensee can test a secondary market to find an alternative buyer for the license. In this market, with probability ½, there is an alternative user of the license with incremental value $100.$ Otherwise, no alternative licensee emerges. For simplicity, assume the licensee will test this market only once.

Long-term Licenses

Suppose the licensee can hold the license indefinitely (unless it chooses to sell the license on the secondary market).

If it chooses to invest in the risky venture and the venture is successful, then it receives a gross gain of $200.$ If the venture is not successful, for low enough values of $c,$ it will choose to investigate the secondary market. In this case, its expected net return is

$$½ *100 +½ *0 –c=50-c.$$

Thus, the net expected return on the risky venture is

$$\alpha 200 + (1- \alpha)(50-c) - K=50 + \alpha 150 -(1- \alpha)c - K .$$

For the investment to be attractive, this amount must be greater than zero:

(*) $$50 + \alpha 150 - (1- \alpha)c – K > 0.$$

Under this condition, the total incremental social surplus generated by the investment would include this net profit plus any incremental consumer surplus, $CS_K,$ generated by the investment but not captured by the licensee.

$$TS = 50 + \alpha 150 - (1- \alpha)c + CS_K – K > 0.$$

Short-term Licenses

Suppose instead that the licensee must reacquire the license at a second price auction within, say *3* periods and that, at such an auction, again with probability *½* an alternative licensee with value of *100* emerges.

If the length of time required before discovering whether the investment is successful is short enough, $T < 3$, then this requirement has no impact on investment incentives (assuming the return is realized before the license must be re-auctioned).

However, if $T > 3$, the incumbent licensee will win at the re-auction only if its expected value going forward exceeds the value of any alternative licensee. Thus, it will win only if either no alternative licensee arrives or if its expected value gross of K exceeds 100:

$$50 + \alpha\, 150 - (1- \alpha)c > 100.$$

Suppose this condition does not hold, (for c very small, this implies $\alpha < 1/3$). In this case, when an alternative licensee emerges, the incumbent would be unwilling to outbid the rival and any investment K would be stranded.

Realizing this possibility, at the time of deciding to invest K, the licensee weighs this cost against the return it will enjoy only if no licensee emerges in the auction. It will choose not to invest if this is too low:

(**) $\quad \frac{1}{2}(50 + \alpha 150 - (1- \alpha)c) - K < 0.$

Thus, for any cost of investment in the interval,

$$\tfrac{1}{2}(50 + \alpha 150 -(1- \alpha)c) < K < (50 + \alpha 150 -(1- \alpha)c),$$

the requirement that the licensee reacquire the license at auction before the realization of the investment would lead the licensee not to take on the endeavor whereas it would have done so had it owned a long-term license. In this case, the negative impact of the short-term license on investment incentives is such as to deny the licensee and the consumers in the market the benefits of the potential long-term investment.

A2: Stranded Assets

In this section I illustrate that a common pricing rule at auction implies that an incumbent licensee that invests and generates a certain but licensee-specific increase in license value is less able to capture the returns to that investment when licenses are short-term than when they are long-term and it can trade on a secondary market.

Consider an alternative scenario. In period 1, an incumbent licensee decides whether to expend K to improve the value of its license. Without an investment, in period 2, the incumbent will learn if its intrinsic value for the license is 0 or 100.[5] Ex ante, each event occurs with equal probability. In period 2, as well, with equal probability, there is a rival licensee that values the license at either 0 or 100. Realizations are independent of each other. An investment increases the value of the license to the licensee alone by V. Thus, if it chooses to invest the values are V and $100 + V$ with equal probability. For brevity, I restrict attention to the case where $V < 100$, so that there is the possibility of the license changing hands at some point. Similar results follow if $V > 100$, though the intuition is somewhat different.

If the incumbent holds a long-term license, it has the option in period 2, to negotiate a price and sale in a secondary market or it can forego obtaining this sale and hold the license itself. If it holds a short-term license, then it can only retain the license by bidding for it in a second price re-auction.

Long-term Licenses

Suppose the licensee can sell the license to the rival in a secondary market if it desires in period 2. Negotiations between the two parties are such that it captures a proportion λ of the gains from trade where λ is between 0 and 1.

With no investment, the value of holding a license to the incumbent is

$$\tfrac{1}{2}\, 100 + \tfrac{1}{4}\, \lambda\, 100$$

where the first component is the value of the license to the incumbent when its second period outcome is good and the second component represents the case where the incumbent's value is low, the rival's value is high and the incumbent captures some of the resulting gains from trade, $\lambda\, 100$.

The value, gross of investment costs, of holding a license is

$$\tfrac{1}{2}\,(100+V) + \tfrac{1}{2}\,(\tfrac{1}{2}V + \tfrac{1}{2}\,((1-\lambda)\,V+\lambda 100)) = \tfrac{1}{2}\,(100+V) + \tfrac{1}{4}\,(V+(1-\lambda)\,V+\lambda 100).$$

The final term reflects the ability of the incumbent, when its intrinsic outcome is bad, to enjoy the returns from the investment (V) when the rival's outcome is bad and *some* of the returns, $(1-\lambda)\,V+\lambda 100$, even when the rival's outcome is good. This final term is higher than the no investment term only if $\lambda < 1$, reflecting the fact that if $\lambda=1$, with or without the investment improvement, it captures all the surplus from its rival. For the event that a rival acquires the license, the value of V to the incumbent lies in its ability to improve the incumbent's bargaining position.

The incremental value of investment over no investment is

[5] These values can be thought of as increments to the current value of holding the license so, in the analysis, the current value is normalized to 0.

$$½ V + ¼ (V+ (1- λ) V) = V - ¼ λ V . \qquad (CL1)$$

The presence of the secondary market reduces somewhat the returns to investment compared to when the market is absent (in which case the returns are simply *V)* unless $λ = 0$. This is because the investment reduces the gains from trade in the event a trade occurs (from 100 to *100-V)* and, with $λ > 0$, the incumbent licensee obtains some share of the gains from the trade.

Short-term Licenses

If the current incumbent must compete in Period 2 for the license, then with no investment, the gross return from holding a license is just its expected return in the auction which is

$$½(½ 100 + ½ 0)= ¼ 100.$$

That is, the return in the event that its value is high and the rival's value is low (times the probability). When the value of both agents is high, then the incumbent either must bid up to its rival's value to obtain it at the re-auction or cede the license and in either case, its net gains are zero.

If the licensee makes the investment, in Period 2, the licensee only loses the license when its outcome is bad and the rival's outcome is good. Assuming the re-auction is a second price auction, if the incumbent obtains the license, it must pay the value of the rival licensee to get it. Thus the gross value is

$$¼ ((100+ V) + (100+ V - 100) +V) = ¼ (3V+100).$$

The incumbent fails to retain the license only if its outcome is bad and the rival's outcome is good. All outcomes occur with probability ¼. On the left side of the expression, the second term represents the case where the incumbent must outbid the rival's bid of *100.* The other two terms represent the case where the rival's outcome is bad and therefore bids *0.*

The incremental return on investment is

$$¼ 3V. \qquad (CS1)$$

Comparisons of the Two License Terms

Comparing (CL1) and (CS1), the difference in investment incentives is

$$V - ¼ λ V - ¼ 3V = ¼ V(1- λ)$$

which is non-positive only if $λ=1$. The increased gains from holding a long-term license in this example derives from the ability of the incumbent to increase its outside option and therefore improve its bargaining position in the secondary market. Only if $λ=1$, then its outside option is irrelevant when bargaining in the secondary market, and so would have no effect.

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Vincent, Daniel R. "Revenue Equivalence, the Winner's Curse and Aftermarket Sales in Auctions." *Proceedings of Spectrum 20/20*. The Radio Advisory Bureau, Ottawa, November 1996.

Vincent, Daniel R. "Comments on 'Review of the Comparative Selection and Radio Licensing Process--Findings'." [Prepared as an Appendix to: Mobility Canada, "Policy Discussion Respecting: 'Review of the Comparative Selection and Radio Licensing Process--Findings'."] June 30, 1996.

Vincent, Daniel R. "Industry Canada is Taking Itself to the Cleaners." *The Globe and Mail*, December 7, 1995.

UNPUBLISHED WORK:

Vincent, Daniel R. and Alejandro Manelli. “Dominant Strategy and Bayesian Implementation in the Multiple Good Environment.”

The paper provides necessary and sufficient conditions for a mechanism to be Bayesian implementable in an independent private values, multi-unit auction with N goods and I bidders. It offers a strong necessary condition for a given revenue-maximizing Bayesian mechanism to be implementable in dominant strategies. A consequence of this condition is the conclusion that, in the multi-unit case, revenue-maximizing Bayesian mechanisms are rarely dominant strategy implementable, in sharp contrast to a result shown by Manelli/Vincent (2010) for the case of single-unit trading mechanisms.

Vincent, Daniel R. and Marius Schwartz. “Platform Competition With User Rebates Under No Surcharge Rules.”

We analyze competing strategic platforms setting fees to a local monopolist merchant and rebates to end users, when the merchant is prevented from surcharging platforms’ customers, as frequently occurs with credit cards. Each platform has an incentive to gain transactions by increasing the spread between its merchant fee and user rebate above its rival's spread. This incentive yields non-existence of pure strategy equilibrium in many natural environments. In some circumstances, there is a mixed strategy equilibrium where platforms choose fee structures that induce the merchant to accept only one platform with equal probability, a form of monopolistic market allocation.

Vincent, Daniel R. “Mixed Bundling and Imperfect Competition.”

The paper examines motivations and consequences of mixed bundling behavior by multi-product duopolies. As in the case of multi-product monopolists, imperfectly competitive multi-product firms

have an incentive to offer rich pricing menus in order to price discriminate. This paper offers a first look at price discrimination under competition and demonstrates an additional source of social harm from mergers even of firms that are horizontally separated as the incentive to mixed bundle reduces the variety of products available.

Vincent, Daniel R. and Alejandro Manelli. "Information Revelation Policies for Sellers at Auction."
In this paper, we show how to construct revenue enhancing seller reporting policies in environments where the classic Milgrom and Weber (1982) assumptions may fail. The technique first transforms a wide class of models into the affiliated values environment. Once in this framework, the standard arguments arguing for information revelation apply. The approach involves a reordering, merging and mixing of seller signals to generate affiliation between the transformed signal and bidder signals. The need to ensure that informational variables are affiliated often requires a reordering of the seller's informational signal. A consequence is that, even if buyer valuations were originally increasing in the seller's signal, they may no longer be increasing in the reported signal. The technique then requires applying a further transformation to ensure that the final seller signal is positively affiliated with bidder *valuations* as well as bidder information and the common value.The latter algorithm can be applied iteratively. Each successive iteration involves the revelation of more (affiliated) information and, thus, the potential for greater revenue enhancement.

TEACHING:

Department Teaching Award, ECON415 Market Design, Spring 2017.
Department Teaching Award, ECON604 Graduate Micro-theory, Spring 2016.
Department Teaching Award, ECON603 Graduate Micro-theory, Fall 2014.
Department Teaching Award, ECON662 Graduate Industrial Organization, Fall 2013.
Department Teaching Award, ECON604 Graduate Micro-theory, Spring 2012.

UNIVERSITY ADMINISTRATIVE DUTIES:

Member, Department Executive Committee, 2016-2017.
Chair, Department Promotion Review Committee, Andrew Sweeting, 2017.
Chair, Department Promotion Review Committee, Erkut Ozbay, 2016.
Member, University Senate, University of Maryland, 2012-2013.
Chair, Department Tenure Review Committee, Emel Filiz Ozbay, 2013.
Chair, Department Tenure Review Committee, Andrew Sweeting, 2013.
Chair, Department Executive Committee, 2012-2013.
Chair, Senior Recruiting Committee, University of Maryland, 2008-2010.
Chair, Department Tenure Review Committee, Alan Sorensen, 2010.
BSOS Dean Search Committee, University of Maryland, 2009.
Departmental Salary Committee, University of Maryland, 2003-2006.
Departmental Chair Search Committee, University of Maryland, 2005.
Co-chair, Departmental Journal Rankings Committee, University of Maryland, 2003-2004.
Departmental Executive Committee, University of Maryland, 2000-2002.
Junior Recruiting Committee, University of Maryland, 1999-2003, 2005-2007.
Ad Hoc Committee on Senior Recruitment, University of Maryland, 1998-99.

P.H.D. THESIS COMMITTEES:

Gail Cohen, Managerial Economics and Decision Sciences, J. L. Kellogg Graduate School, Northwestern University, 1992.
Topic: Essays in Industrial Organization.
Currently at Federal Energy Commission, Washington, DC.

Brian Rivard, Department of Economics, University of Western Ontario, 1996.
Topic: An Imperfect Competition Suite.
First position: Competition Bureau, Industry Canada, Ottawa.

Benoit Julien, Department of Economics, University of Western Ontario, 1996.
Topic: Essays on Auctions and Contracts
Currently on Faculty at Department of Economics, University of Miami.

Soamiely Andriamananjara, Department of Economics, University of Maryland, 1999.
Topic: Regionalism and Its Effects on Multilateralism
First position: International Trade Commission.

Jesse Schwartz, Department of Economics, University of Maryland, 1999.
Topic: Demand Reduction in Multiple Unit Ascending Auctions
First position: Department of Economics, Vanderbilt University.

Gary Anderson, Department of Economics, University of Maryland, 1999.
Topic: Multinational Corporations and Developing Countries
First position: ITAM, Mexico City, Mexico.

Gwen Alexander, Department of Economics, University of Maryland, 2000.
Topic: Essays in MicroFinance.

Jeff Lien, Department of Economics, University of Maryland, 2000.
Topic: The Strategic Use of Forward Contracts: Applications to Power Markets.
Currently at the U.S. Department of Justice, Antitrust Division.

Haiwen Zhou, Department of Economics, University of Maryland, 2002.
Topic: Three Essays on Industrial Organization.
Currently at Old Dominion University.

Nisvan Erkal, Department of Economics, University of Maryland, 2002.
Topic: Essays on Innovation, Disclosure and Product Choice
Currently at the University of Melbourne.

Roberto Munoz, Department of Economics, University of Maryland, 2003.
Topic: Essays on "The Role of Private Benefits on the Efficient Transfer of Control in a Firm and Equilibrium Selection in a Link Formation Game."

Ashish Narain, Department of Economics, University of Maryland, 2003.
Topic: Capital Mobility, Trade Liberalization and Unions.

Kyeong-Hoon Kang, Department of Economics, University of Maryland, 2003.
Topic: Market Structure and Competition in Systems Markets.
Currently at Korea Institute of Finance.

Patricia Tovar Rodriguez, Department of Economics, University of Maryland, 2005.
Topic: The effects of loss aversion on trade policy. Currently at Brandeis University.

Min Ouyang, Department of Economics, University of Maryland, 2005.
Topic: Resource reallocation, productivity dynamics, and business cycles.
Currently at U.C.-Irvine .

Heisnam Singh, Department of Economics, University of Maryland, 2007.
Topic: Essays on price competition and firm strategies in oligopolies. Currently at PwC.

Natalia Perez, Department of Economics, University of Maryland, 2007.
Topic: Essays on the Impact of Social Interactions on
Economic Outcomes. Currenlty at Ernst and Young.

Thayer Morrill. Department of Economics, University of Maryland, 2008.
Topic: Three essays on market design. Currently at North Carolina State University.

Grozeva, Vesela. Department of Economics, University of Maryland, 2010.
Topic: Dynamic Competition with Customer Recognition and Switching Costs. Currently at Ernst and Young.

Johnson, Terence. Department of Economics, University of Maryland, 2011.
Topic:. Essays on Auction and Matching Theory, Currently at Department of Economics, University of Notre Dame.

Vamosiu, Adriana. Department of Economics, University of Maryland, 2013. Appointed to Department of Economics, University of San Diego.

CONSULTING:

Principal, Market Design Incorporated (MDI), Stanford, CA.

Consultant on Various Anti-trust Matters, (via Compass-Lexecon) 2016.

Consultant for Verizon Wireless, FCC Incentive Auctions. 2012-2015.

Consultant for a bidder, FCC Incentive Auctions. 2016-2017.

Consultant for a party concerning the ATT-DTV Merger and Comcast-TWI merger, 2014.

Consultant for Videotron, Analysis of the U.S. 700MHZ Auctions, 2012.

Consultant for a party concerning the ATT-T-Mobile Merger, 2011.

Consultant for the U.S. Department of Justice, Antitrust Division, various antitrust matters: 2000-2013.

Consultant for a party concerning the Google-Yahoo Alliance, 2008.

Consultant for Videotron, Industry Canada AWS Auctions, 2008.

Consultant for Cox, U.S.700MHZ Spectrum Auctions, 2008.

Consultant on Canadian Spectrum Issues, Lemay-Yates Associates, 2007.

Consultant for Time-Warner, U.S. AWS Spectrum Auctions, 2006.

Consultant for Exelon, Illinois Electric Load Auction, 2006.

Consultant for an auction client (through NERA), 2002, 2003.

Consultant for the National Football League, (with Marius Schwartz), 2003.

Consultant for the National Association of Station Affiliates, (with Marius Schwartz), 2002-2003.

Consultant for Industry Canada. Review of auction rules for PCS auctions. (Joint with MDI/CRA), June, 2000.

Consultant for a participant in the Alberta, PPA auctions, Spring, 2000--

Consultant for OFCOM, Switzerland. Design of auction for UMTS 3G services. Spring, 2000 --

Consultant for a participant in U.K. UMTS 3G spectrum auctions, January-March, 2000.

Consultant for a participant in Industry Canada, 24-38MHZ spectrum auctions, November, 1999.

Consultant for the Federal Communications Commission. Modification of Auction Rules for Combinatorial Bidding. (Joint with MDI/CRA). 1997-1998.

Consultant for the Federal Communications Commission--Assessment of U.S. Spectrum Auctions and Auctions Adviser--1997.

Consultant for Industry Canada, "Assessment of the Market Value of Cellular Telephones, Personal Communication Services and Enhanced Specialized Mobile Radio License Fees," 1996-1997.

Consultant for TELUS on Industry Canada's proposal for a revision of the radio frequency licensing process.

Consultant for Ameritech, Chicago, IL (D and E Block BTA Auctions, 1995.)

Consultant on 1994 FCC Spectrum Auction Design for American Personal Communications, Washington, D.C. (Auction design phase).

Consultant on Tariff-Quota Equivalents and Auction Data for the World Bank, 1992 to 1994.

Consultant on Procurement Methods for the Bank of Spain, 1994.

PROFESSIONAL SERVICE:

Invited Speaker, Federal Communications Commission, Video Market Workshop, March 21, 2016.

Associate Editor, *Journal of Economic Theory*, Summer 1996- Spring, 2003.

Member, Editorial Board, *American Economic Review,* 2000 - 2006.

Invited Lecturer, World Bank, Transparency in Infrastructure, March, November, 2002, January, 2004.

Invited Lecturer, Harvard Institute for International Development, Privatization Project, July, 2000.

REFEREEING:

(i) Journals

American Economic Review
Econometrica
Economic Design
Economic Inquiry
Economic Theory
Games and Economic Behavior
Journal of Economics and Management Strategy
Journal of Economics and Statistics
Journal of Economic Theory
Journal of Industrial Economics
Journal of Law, Economics and Organization
Journal of Public Economics
Quarterly Journal of Economics
Rand Journal of Economics
Review of Economic Studies

(ii) Research Organizations

National Science Foundation
Social Sciences and Humanities Research Council of Canada

RESEARCH GRANTS:

2003-2006 National Science Foundation Grant # 0241173, ARevenue Maximization in Multi-Object Auctions@.

2001-2003 National Science Foundation Grant # 0095729, AInformation Revelation Policies for Sellers at Auction@

1996-1999 "Auction Theory and Empirical Applications" $50,000
SSHRC